

Achieving Robust Operational METOC* Forecasts

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It is becoming quite apparent that many aspects of Atmospheric, Ocean and Ice Operational Forecasting are increasing. This includes the number of operational forecast centers in existence; the range of parameters forecast; and the product resolution in time and space. In fact, at many levels it is easier to form a new center, generate new products, or increase the resolution, than it is to ground-truth the forecasts at comparable space and time scales. This paper addresses four methods that may help to achieve more robust operational forecasts.

- 1) *Target R&D based on gaps relative to performance and requirements.* Operational model prediction systems and their forecast products represent that portion of our knowledge synthesis, which is capable of being programmed into a computer. Generally, they are correct to first order and are more helpful than not. It is sifting through the order 2 issues where difficulty arises, as many factors come into play and / or have feedback loops, e.g., numerical formulation, boundary conditions, boundary layer dynamics, sub grid-scale parameterizations and quantity/quality of data for assimilation. There is no shortage of applied / basic researchers worldwide with local/regional and observational/theoretical expertise to sort through these issues. The main barrier to progress is limited quantitative scrutiny as a direct result of restricted access to the operational forecasts. In order to spur METOC scientific advances, the US Navy is willing to barter operational forecasts in exchange for evaluations of their performance. Evaluations by regional experts with regional data is felt to be one of the quickest routes to attaining robust products; exchanges of gridded forecast fields, regional data sets, as well as personnel will be emphasized.
- 2) *Synergism between International R&D efforts.* There is considerable investment around the globe on modeling short-term "weather" forecasts (nowcasts - 10 days) as well as climate change time scales (seasonal - century). All scales require at least coupled atmospheric and ocean components, further complexity comes from adding surface waves, ice, sediment transport, contaminant transport and ecosystem modules.

For smaller nations with limited forecast infrastructure, it can be possible to utilize internationally funded efforts to gain at least some capability. For instance, the European Commission has just concluded funding of a coupled hydrodynamic-ecological model for use as a community model

(COHERENS). It is available as freeware, is modular in design, well documented and runs on PC, MAC or UNIX (<http://www.mumm.ac.be/~patrick/mast/>). Developed over a decade by an international group of scientists, it has all the components mentioned above except surface waves and ice, and represents a substantial "jump-start" to any nation interested in gaining an interpretive and forecast tool for their coastal waters. The model requires meteorological forcing at a minimum. Via another international program, the Global Ocean Data Assimilation Experiment (GODAE, <http://www.usgodae.fnmoc.navy.mil>), the US Navy will soon be putting out its global 1 degree, 5 day atmospheric forecast. With the US Navy surface fields to drive COHERENS, two essential building blocks for understanding and forecasting the coastal marine environment are now readily available. This represents a significant step forward in capacity and infrastructure building.

There are numerous international efforts involved in funding regional observing systems which could utilize this combination of surface forcing and modeling as a common forecasting basis, e.g., the regional GOOS (<http://ioc.unesco.org/goos/goostoc.htm>), the Large Marine Ecosystems of the Global Environmental Facility (<http://www.undp.org/gef/portf/waters.htm>), and the US Integrated Ocean Observing System (<http://core.cast.msstate.edu/oceanobs.html>). As suggested in (1) above, the more scrutiny of model performance, the easier it will be to identify performance shortcomings and target required R&D. By evaluating the same forcing & model in different dynamic regimes (tropics, subtropics, polar), the more potential insight there is to be gained. A pivotal aspect of this scenario, is that regional observing systems should be connected to the Global Telecommunications Service of the WMO. This regional data could then be assimilated by the remote centers, and presumably, the regional forecasting and boundary conditions would be improved. The conclusion of course, is that by sharing data, international synergism builds, furthering science/environmental understanding and advancement.

- 3) *Coastal Bathymetry is an Essential Infrastructure.* Global Meteorology and Ocean Basin boundary conditions are essential for driving regional / meso-scale models as remote influences/processes can play an order 1 role in the regional response. Additional boundary condition requirements for regional models are topographic and bathymetric resolution on scales comparable to or finer than those of the model resolution. For obvious reasons, bathymetry is the more difficult to attain, and transboundary issues associated with exclusive economic zones and territorial waters are additional complicating factors. As mentioned above, global boundary forcing is becoming available through international scientific investigations (GODAE) or through barter arrangement with the USN (1, 2 above). What is less well known is the existence of cooperative hydrographic and oceanographic survey programs, two of which are conducted by the French and US Navies (SHOM,

NAVOCEANO, respectively), which can be quite helpful to those nations lacking the necessary ships, equipment and processing capabilities to survey their waters. These organizations conduct schools to train hydrographers, and provide survey equipment and ships which can be used to survey other nations ports, harbors, estuaries, and coasts. The typical quid-pro-quo in these agreements is a copy of any data collected. In all cases, further release of the data is controlled by the originating nation. Up-to-date bathymetry is an infrastructure requirement which cannot be put into place quickly. As with any forecast, the boundary conditions can drive the performance skill. Without accurate bathymetry, poor regional forecast performance and coastal zone management is a likely conclusion. The time to start updating coastal bathymetric data bases is now, as the forecasting ability already exists.

- 4) *Enable digital feedback from operational forecast customers.* In discussions with US Navy customers and model developers, there was strong consensus to increase the number and quality of operational evaluations and collate and share them in digital form. In conjunction with the US model developers and operational center staff, the author developed a web-based form for evaluating METOC products for US operational forecast products. The resulting web-based survey form (point and click radio button choices, fill in the blanks, etc) will be filled out and stored electronically. On-line evaluators will send the evaluations to the operational center, as they can benefit directly and utilize the feedback immediately to improve their forecasts. The operational center will then forward their collated evaluations (by product and region) to a central collection point, for scrutiny by the model developers for each product and improvements/fixes implemented and or researched. At a minimum, this process will provide a quantitative time-history of model tendencies/biases/performance as well as product preferences/usage and can be used to set priorities for model improvements and new product development. A copy of this evaluation form can be retrieved via anonymous ftp: [<ftp://ftp.onr.navy.mil> change to directory PUB/BEACH/METOC the file is: Op4casteval.htm].

*METOC: abbreviation for Meteorology and Oceanography